APPENDIX C THE ENERGY 2020 MODEL

C.1. ENERGY 2020 – The Energy Model

ENERGY 2020 is a system dynamics model developed by Systematic Solutions, Inc. (SSI), and designed especially for comprehensive energy planning at a regional level. The complete ENERGY 2020 model integrates energy demand, energy supply, and the economy, allowing policy analyses to be performed. Specifically, ENERGY 2020 simulates the major departments of regulated electric and gas utilities, other energy supply sources, and the major components of energy demand, including transportation demand, in a single comprehensive framework connected by several important feedback responses. The interactions among all the components of the energy system are consistently represented.

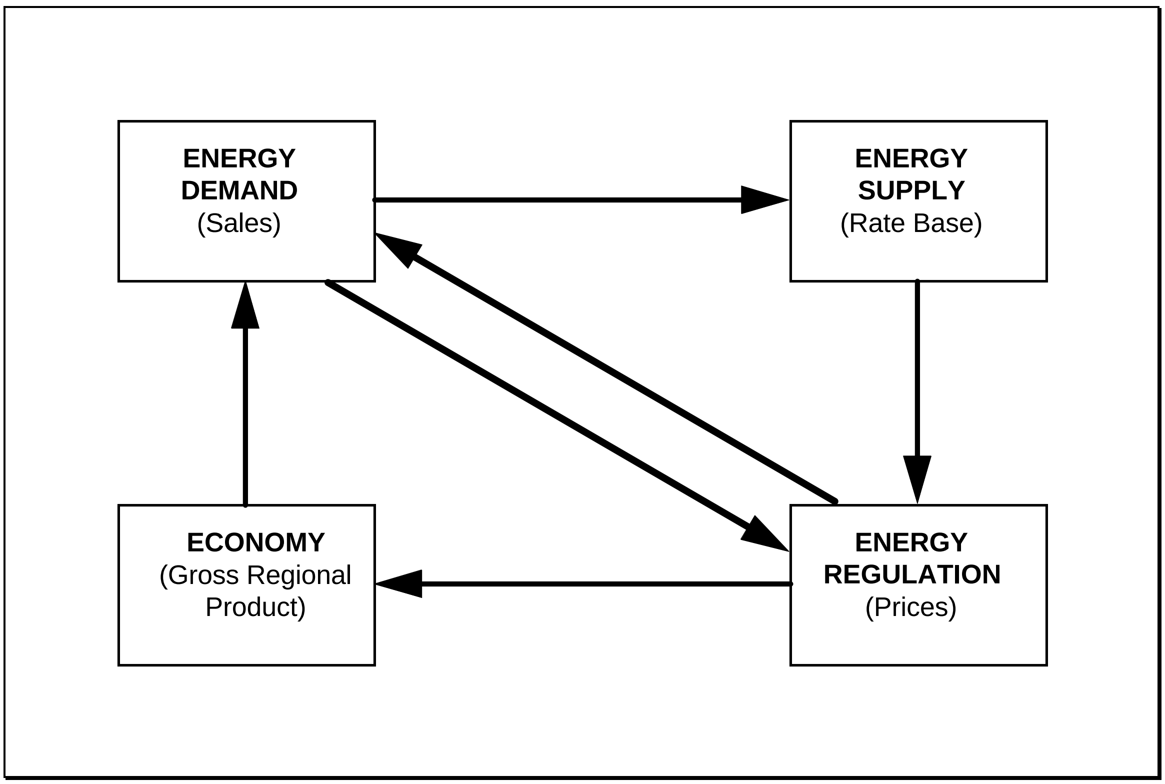

Figure C-1. Feedback Loops Linking the Components of ENERGY 2020

Figure C-1 illustrates the basic feedback loops in ENERGY 2020. Through causal modeling, in combination with econometric, engineering, and system dynamics techniques, the closed loop system is simulated. There are many interconnections between the four segments (boxes). These result in feedback, which must be taken into account. Some relationships reinforce behaviors, while others stabilize and control the system by countering any disturbance. In some instances, the effect of policies and programs in the long-term will be opposite the effect in the short-term. Thus, for robust planning, it is important that dynamic behaviors over time be explicitly addressed.

C.1.1. The Structure of ENERGY 2020

The structure of the ENERGY 2020 model, representing how decision-makers act, determines the model results. The ENERGY 2020 model is calibrated to replicate history. This is important because unless a model can reproduce history, the user will have little confidence that it can legitimately represent the future. However, because ENERGY 2020 simulates how participants in an energy system make decisions, it is also able to determine how decision makers may act when they are faced with conditions for which there is no historical precedent.

In an internally consistent manner, the ENERGY 2020 scenario framework integrates all three major components of the energy system: the economy of the county (or utility service area), the energy demands of the county or utility-service-area consumers, and energy supplies.

Each of these components is represented by one or more sectors. Four detailed demand modules – one each for the counties of Hawaii, Kauai, and Maui, and the City and County of Honolulu – were linked with the corresponding macroeconomic models designed by Regional Economic Models, Inc. (REMI). These were also linked to explicitly modeled electric utility, ground transportation, and both bottled gas and utility-gas sectors. Oil refining, air transportation, and marine transportation were modeled at the State level. Demand was divided into four customer classes: residential, commercial, industrial, and transportation. These, in turn, were disaggregated into numerous end-use groups.

ENERGY 2020 models the demand for energy services. It takes into account many factors affecting energy choices including both device and process efficiency choices; the consumer's budget constraints, preferences, and information requirements; economic growth impacts; changes in technology; and take-back dynamics. ENERGY 2020 causally formulates the energy demand equation. It explicitly identifies the multiple ways price changes influence the relative economics of alternative technologies and behaviors, which in turn determine consumer demands. In this sense, price elasticities are outputs, not inputs, of ENERGY 2020. The model recognizes that price responses vary over time and depend upon factors such as the rate of investment, the age and efficiency of the capital stock, and the relative prices of alternative technologies. Figure C-2 illustrates the basic demand configuration of ENERGY 2020.

The basic supply sector of ENERGY 2020 provides price feedback to the demand and economy sectors. The supply sector includes not only the energy-producing and energy-delivering companies, but also the regulators and market mechanisms.

ENERGY 2020 also simulates the detailed operation of Hawaii's four regulated electric companies and its one regulated gas company. Figure C-3 depicts the basic ENERGY 2020 electric utility sector. The model endogenously forecasts

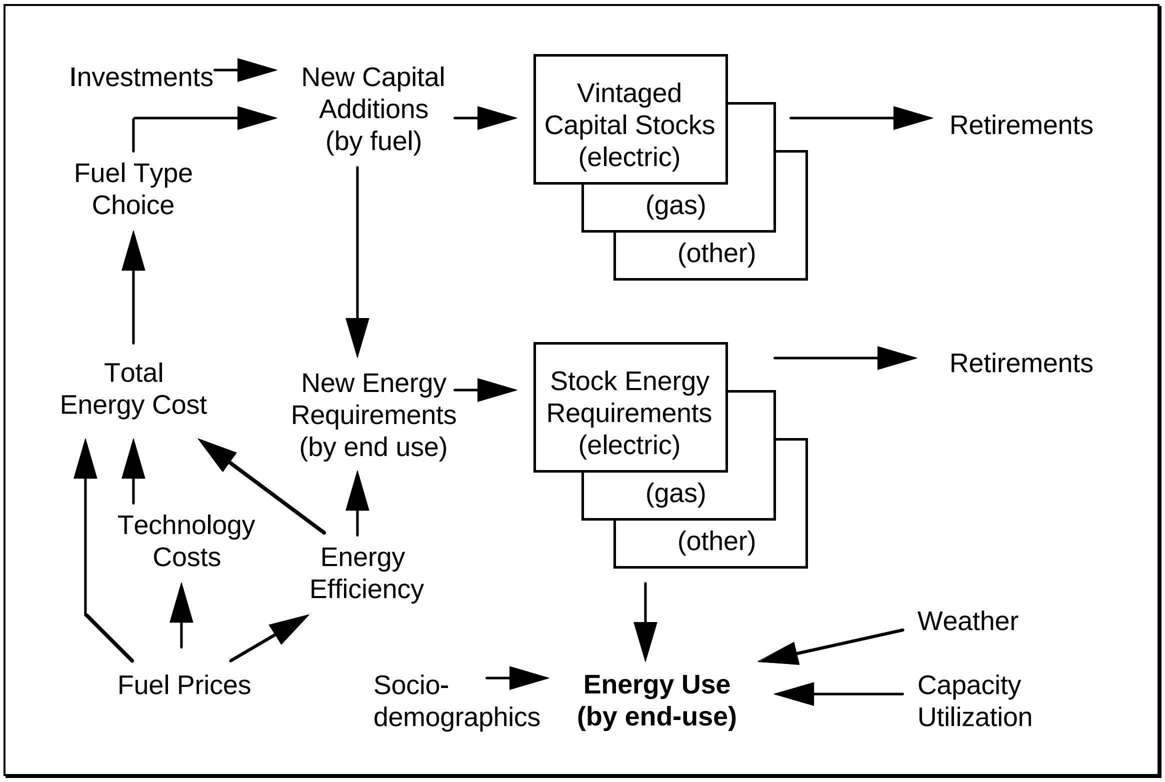

Figure C-2. ENERGY 2020 Demand Configuration

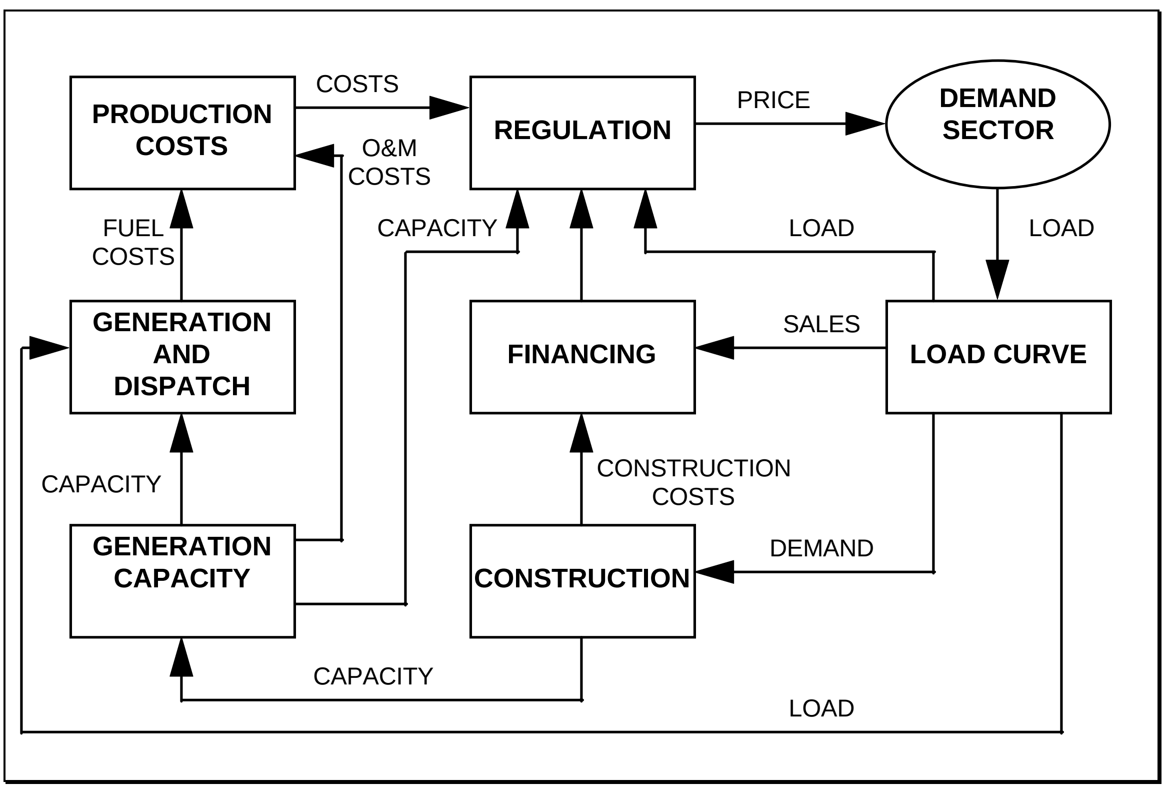

Figure C-3. Basic ENERGY 2020 Electric Utility Sector capacity needs, as well as the planning, construction, operation, and retirement of generating plants and transmission facilities. In the model, revenues, debt, and the sale of stock finance each step. Like their real-world counterparts, the simulated utilities pay taxes. The model also generates a complete set of accounting records. In ENERGY 2020, the regulatory function is modeled as a part of the utility sector. The regulator sets the allowed rate of return; divides revenue responsibility among customer classes; approves rate base, revenues, and expenses; and sets fuel adjustment charges. Detailed supply sectors for oil refining on Oahu, and air and marine transportation statewide, were also explicitly modeled.

A pollution or emission accounting module in ENERGY 2020 tracks pollution generation by end-use and fuel type from the demand sector, and from the utility sector by supply and plant type. ENERGY 2020's pollution accounting module also tracks energy-related pollution in the transportation sector by mode and in the industrial sector by two-digit Bureau of Labor Statistics Standard Industrial Code (SIC) code. The program also tracks greenhouse gases CO_2, CH_4, and N_2O. The levels of pollution generated are fed back to the supply sectors, which allows policies to be introduced that adjust production to meet environmental constraints.

C.1.2. ENERGY 2020 Data Sources

ENERGY 2020's internal national and state databases contain historical economic, price, and demand data by economic sector, fuel, and end-use. Regional and utility-specific data override and supplement aggregate data when available. The Hawaii configuration of ENERGY 2020 used the reports from HES Projects 2, 3, 4, and 5; Federal Energy Regulatory Commission (FERC) Form 1; FERC Annual Reports; and utility Integrated Resource Plans (IRPs); as well as other local data supplied by DBEDT to model the economy sectors.

C.2. ENERGY 2020 and the REMI Economic Model

A macroeconomic forecasting model developed by Regional Economic Models, Inc., is used to create the specific economic drivers for ENERGY 2020's energy forecast. The current state population and economic forecast (State of Hawaii, 1997b) was used to calibrate the REMI model, and the REMI model was used to forecast economic drivers. The REMI service-area-specific model simulated the competition between the local service area and the "rest-of-the-world" for markets, business, and population. When linked to REMI, ENERGY 2020 captures the feedback impacts of rates, construction, and conservation programs on local economic growth, employment, and energy use.

C.2.1. The REMI Model and Its Relationship to ENERGY 2020

Four integrated economic and energy models representing the four counties Honolulu (Oahu), Maui (including Molokai and Lanai), Hawaii, and Kauai were developed. Each has a REMI model simulating the economic future of that county and an appropriate version of ENERGY 2020 simulating that county's energy markets. When all four county models are run simultaneously, inter-County interactions are captured, as the forecast is executed a year at a time.

ENERGY 2020 is fully linked with the REMI model, which allows energy prices and price changes generated in ENERGY 2020 to interact dynamically with REMI's economic forecast. The forecast economic changes then flow back to ENERGY 2020, affecting future demand, utility rates, and resource planning.

Personal income and gross output by industry from the REMI model are the principal drivers for ENERGY 2020. Other REMI variables used in the ENERGY 2020 databases include population, new capital investment, gross state product (GSP), and employment. The different sectors of ENERGY 2020 in the Hawaii model include residential, commercial, industrial, and transportation demands; electric utility, regulated utility, and unregulated gas service; and oil refining. Each is driven by one or more economic variable. For example, personal income is the principal driver for the residential sector, while gross output by industry is the principal driver for the commercial and industrial sectors. Policies developed for the regulated and unregulated energy sectors cause energy price changes and possible direct changes in employment. These, when fed back into the REMI model, affect the drivers of the other sectors. REMI outputs drive ENERGY 2020, and ENERGY 2020 outputs, in turn, influence the REMI simulations.

Prior to the Hawaii Energy Strategy project, ENERGY 2020 and REMI were linked principally through energy-price feedback loops that allowed the simulation of economic changes from changing electricity and gas prices. Because the Hawaii version of the ENERGY 2020 model required more detail, new feedback loops from utility policy simulations (e.g., supply side, DSM, and economic impacts from transportation policies) were developed and incorporated into the linkage structure. Therefore, the baseline economic forecasts described include any economic alteration from the feedback effects of ENERGY 2020's baseline outputs. As energy policies are developed, changed, and implemented, the model captures these effects and causes the baseline economic simulation to change accordingly.

The basic structure of the REMI model is shown in Figure C-4. The model is composed of five sectors, termed linkages by REMI . They are output, demand (for both labor and capital), supply (of population and labor), market share, and wages (including prices and profits). These parts are linked to each other through common variables. The local demand for components of personal consumption determined in the output linkage is a function of real income, investment, and government expenditures. Investment demand is also endogenously determined and is a function of both relative factor prices and expected economic activity. Government expenditures depend in part on the size of the local population. When coupled with export demand, these demands determine industry demand by sector and the industry output of the model.

C.2.2. Structure of the REMI Model

The employment demand by industry and occupation is a function of local output, determined in the output linkage, and of the number of employees per dollar of output. The latter is determined in part by the relative costs and substitutability of all the factors of production. The structure of the REMI model is shown in Figure C-4.

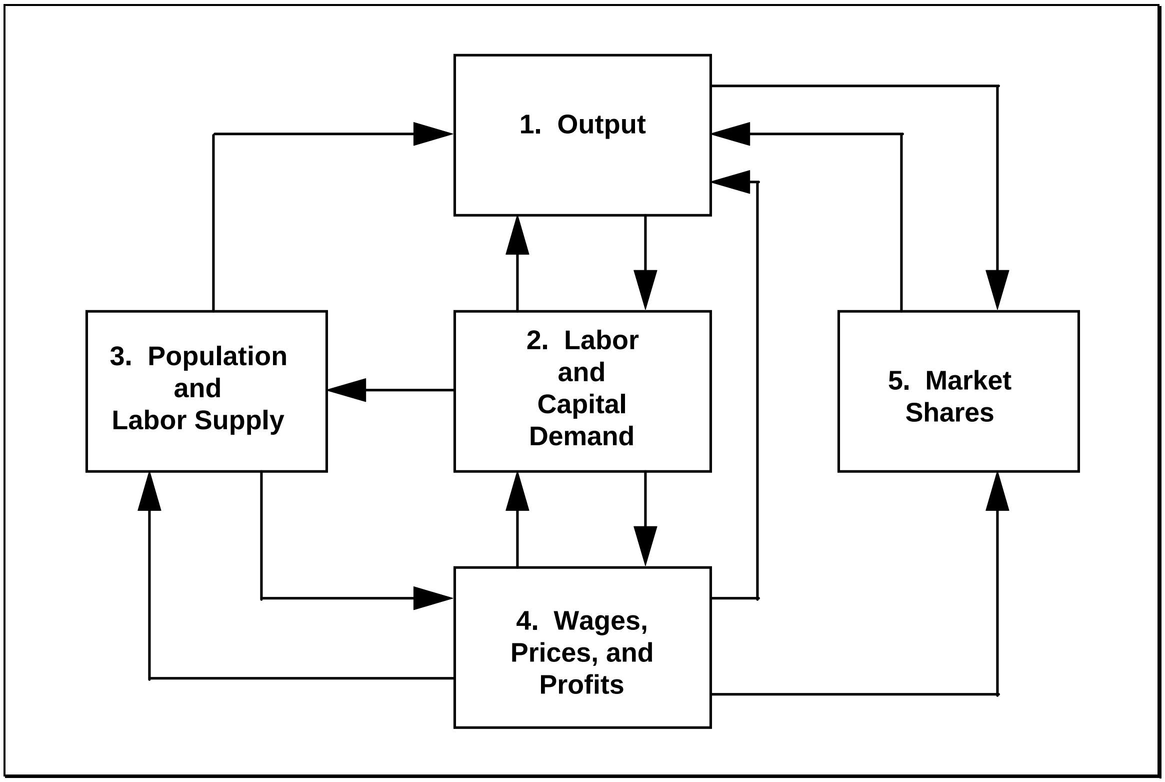

Figure C-4. Structure of the REMI Model

Labor supply and population are closely linked. Population by age and sex in the REMI model is calculated in the demographic/migration module from interactions of natural causes (e.g., births and deaths) and migration shifts (for economic or other reasons). Therefore, population depends on migration (retirement, military, international, and economic) as well as on the cohort survival aspects of population change. Natural population changes are derived from appropriate fertility and survival rates. Economic migration further depends on expected income, which is calculated from the employment/labor force ratio, the real wage rate, and the mix of industries.

The wage rates are determined by the aggregate employment/labor-force ratio and occupation-specific demand and supply conditions.

Market shares, both locally and in the export market, depend on selling prices and profitability – the ability to compete. Competitive pricing depends on factor costs including the cost of labor.

C.2.3 REMI Data Sources

C.2.3.1 Primary Historical Data

A complete documentation of the data sources used in REMI (definitions, descriptions, and estimation procedures for missing data) can be found in Chapter IV of *Model Documentation for the REMI EDFS-53 Forecasting and Simulation Model*, March 1997, Volume 1 (Treyz 1997). The primary historical data source is the Bureau of Economic Analysis (BEA) employment, wage, and personal income series covering the years from 1969, which is available for counties at the one-digit SIC code level. A secondary source is the Bureau of Labor Statistics (BLS) data on annual average employment and total annual wages. Supplementary data sources such as *County Business Patterns* (CBP) data were also used when available.

C.2.3.2 Supplemental Historical Data

State-specific fuel-cost data came from the EIA's *State Price and Expenditure Report*. Fuel-weight data by SIC code came from 1982 *Census of Manufacturers – Subject Series*; Table 3 1982 Census of Manufacturers was used for manufacturing. Other census data was used for construction, service, retail and wholesale trade, and agriculture. EIA data were used for transportation and public utilities.

Tax data used to calculate the cost of capital and to estimate residential and non-residential capital stock came from the *Government Finances* (Revenue) publication and the *Survey of Current Business.* Gross State Product (GSP) data came from BEA and BLS (U.S. input-output table) and the *Survey of Current Business.* Data on housing prices came from the *Census of Housing*.

C.2.3.3 National Forecast Data

The primary set of projections used in the REMI model came from the BLS Outlook 2005 projections published in the November 1991 issue of the *Monthly Labor Review.* Data for compiling the output time series for manufacturing industries are in the U.S. Census and the *Annual Survey of Manufacturers*. For non-manufacturing industries, a variety of sources were used including *Service Annual Survey, National Income and Products Accounts* data, *IRS Business Income Tax Receipts*, and other sources.

The 1990 Bureau of Census Survey provides initial population data that were normalized to data from the BEA. Data from Current Population Reports provides fertility and survival rates and five-year cohort rates, as well as data on international immigration. Birth and death rates came from the *Statistical Abstract of the United States.* Other sources of data were used for specific components of migration. REMI uses a linearly trended forecast from 1990 to 2005. After 2005, the BLS moderate-growth labor force participation rates and the Census Bureau's middle population projections for the U.S. were used to forecast the labor force. Business cycles were added to the U.S. forecast from the short-term national forecast from the University of Michigan's Research Seminar in Quantitative Economics (RSQE). Occupation demands were derived from a fixed-proportion occupation-by-industry matrix based on the BLS 1990 and projected 2005 National OES Matrices.

C.2.4 Adjustments to REMI Default Data

REMI data from national sources can be overridden with better local data when it is available. For the initial REMI forecast, most of the default data were used with the following exceptions. Local estimates of military employment were used in place of the REMI default data. The national trend is a reduced presence of the military in most local economies, but in Hawaii, because of its strategic location, military downsizing has not occurred to the same extent as in the rest of the United States. The military employment estimates from the utility IRPs were used in place of the default REMI data.

State and local government employment was altered to account for local sentiment against the growth of this sector. The population-driven REMI variable was modified to reflect the trend toward a smaller government presence in the counties where the initial REMI percentages were relatively higher.

Hawaii's tourism-driven economy makes forecasting tourist arrivals very important. The REMI model alone does not forecast visitor census (although it is a policy variable in the model). However, the REMI/ENERGY 2020 interface produces a visitor census calculation and a forecast of de facto population in a post-processing routine. As proxy variables for number of tourists, the service industry variables simulated by REMI were evaluated and compared with projected growth rates in the number of tourists.

Hotel sales were altered, if necessary and when possible, to grow at a rate compatible with the rate that is forecast for future tourists. These tourists come Rim countries are increasing in importance, and Canada sends a significant number of tourists to Hawaii every year as well. The increase in sales reflects both the anticipated increase in tourist numbers and the different spending patterns of Japanese and U.S. tourists.

In addition to the specific changes above, the initial REMI forecast was further altered by the changes caused by the feedback loops in ENERGY 2020 that modify energy prices. Many energy policies simulated in the model resulted in relatively small changes to the baseline economic forecast. These differences were generally ignored.